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FIRST INTERNATIONAL CONFERENCE ON FIRE SUPPRESSION RESEARCH: SUMMARY

Vilhelm Sjolin, David D. Evans, and Nora H. Jason, Editors

United States Department of Commerce
Technology Administration
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S115-87 Stockholm, Sweden

and

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Building and Fire Research Laboratory

October 1992

U.S. Department of Commerce
Barbara Hackman Franklin, *Secretary*
Technology Administration
Robert M. White, *Under Secretary for Technology*
National Institute of Standards and Technology
John W. Lyons, *Director*

PREFACE

The Stockholm conference was organized to bring together a cross-section of the researchers, users, and sponsors of fire research suppression worldwide. BRANDFORSK has funded research in Sweden and in other countries for more than a decade, thus allowing the development of extensive contacts with many researchers. During visits of Dr. Vilhelm Sjolin to the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology **(NIST),** a joint interest developed with Dr. David D. Evans for organizing for the first time a conference entirely devoted to fire suppression. It was decided that such a conference should be arranged in Stockholm in May 1992, jointly organized by BRANDFORSK and NIST. Plans for the conference were endorsed by the BRANDFORSK Board of Directors and Dr. Jack E. Snell, Deputy Director of BFRL.

The conference was the first one to be entirely devoted to fire suppression research and from the beginning it was decided to have a broad program. Scientists, sponsors, and users were represented. **To** provide an environment that would enhance information exchange, the number of participants was limited to approximately thirty people.

The conference goals were to:

- present ongoing or recently conducted research;
- present views on what type of projects, types of suppression research, etc., should be undertaken in the future;
- rank future research needs;
- stimulate an exchange of knowledge and provide a foundation for continuing this exchange in the future.

To achieve these goals, the organizers invited individuals representing a broad range of technical expertise, experience, and responsibility in their respective organizations from around the world to submit abstracts. The response was overwhelming. Representatives from Canada, Finland, Germany, Norway, Sweden, United Kingdom and the United States were able to participate.

The speakers presented state-of-the-art papers on specific types of suppression or summarized suppression research within their countries. With this background, the speakers were divided into three panels: Manual Fire Fighting; Fixed Systems; Next Generation Agents. The panel themes were identified prior to the conference when participants developed a list **of** priorities that they felt should be addressed during one or more of the panel sessions. This list was provided to the Panel Chairs to serve as a point of departure for the discussion periods. After intensive discussions, each Panel Chair summarized the priorities to the entire assembly. It also should be mentioned that participants could move amongst the panels, either to provide additional input to the discussions or to act as an observer. To gain a sense of which priorities were the most important, a voting technique was devised. Each participant could **cast** a total of from one to five votes for the priorities within each panel. The resulting rankings reflect a cursory assessment of the group's recommendations which in part reflects the background, expertise, and current interest areas of the participants. If more time was allowed for discussion by the group as a whole, different rankings may have resulted.

The proceedings brings together both aspects of the conference. Individual papers are included in their entirety, as well as the methodology and the research recommendations. It is our hope that the proceedings can serve as a resource to fire research organizations worldwide during the development **of** their short and long term projects.

The response to the opportunities provided by the gathering of fire suppression researchers, users, and sponsors at a conference devoted specifically to fire suppression was enthusiastic and greater than initially expected. **As** a result of the interactions at the conference, each participant has taken away a better awareness of research activities worldwide and new or renewed relationships with others in the community. There is an expectation that there also will be a long term impact on suppression research priorities as a result of the exchange of ideas about research needs. It is clear to us that the benefits of this type of professional interaction are ***so*** substantial that this process must continue with **a** Second International Conference.

We would like to express our gratitude to **Ms.** Nora H. Jason for her tireless **efforts** in organizing and maintaining strict schedules throughout the pre-conference and post-conference preparations, including the final product of the conference, the proceedings. Social arrangement activities, transportation activities and support activities in Stockholm by Ms. Eila Sporrong and **Ms.** Maj Alvinger are gratefully acknowledged. Dr. Ulf Wickstrom and his staff at Borås presented an excellent agenda and it afforded an appropriate conclusion to the conference.

October 1992

Whelm Sjolin
BRANDFORSK

David D. Evans
NIST

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FIRST INTERNATIONAL CONFERENCE ON FIRE SUPPRESSION RESEARCH
Stockholm and **Boras, Sweden**
May 5-8, 1992

May **4** Monday	1930-- 2100	Welcoming Reception for Participants and Spouses at the Hotel Continental

May 5 Tuesday

0815 Hotel Continental Lobby - transportation to the Swedish Fire Research Board (SFRB)

Dr. Vilhelm Sjolin, Chair

0900 Welcome - Dr. Vilhelm Sjolin, Swedish Fire Research Board
Dr. Vilhelm Sjolin, *Suppression Research: Users Needs*

0930 Dr. David D. Evans, National Institute of Standards and Technology, *Suppression Research: Strategies*

1000 Dr. Heimo Tuovinen and Dr. Goran **S.** Holmstedt, Lund Institute of Technology, *Computer Modelling of Extinction of Methane-Air Premixed Flames by Thermally Stable Gases*

1030 Coffee Break

1100 Cheng Yao, Factory Mutual Research Corporation, *Overview of FMRC's Sprinkler Technology Research*

1130 Dr. Paul G. Seeger, Forschungsstelle fur Brandschutztechnik, *Rack Storage Fire Suppression by Sprinklers. Work at the Research Station for Fire Protection Technology*

1200 Dr. Ragnar Wighus, Norwegian Fire Research Laboratory, *Fire Suppression Research in Norway*

1230 Lunch at SFRB

Dr. David D. Evans, Chair

1330 J. R. Mawhinney, National Research Council, Canada, *Fine Water Spray Fire Suppression Project*

1400 Dr. Matti Kokkala, VTT Fire Technology Laboratory, *Fixed Water Sprays Against Open Liquid Pool Fires*

1430 Louise A. Jackman, South Bank Polytechnic, *Characterization of Water Droplets from Sprinkler Sprays*

1500 Break

1530 Russell P. Fleming, National Fire Sprinkler Association, Inc., *Impact of Fire Research on Automatic Sprinkler System Design*

1600 Haukur Ingason, Swedish National Testing and Research Institute, *A Study of Parameters Influencing the RTI Value*

1630 Louise A. Jackman, South Bank Polytechnic, *Interaction of Sprinkler Spray Drops with Fire Gases*

1700 End of Day 1
Transportation to Hotel Continental
1830 Hotel Continental pickup for dinner

May **6** Wednesday

0830 Hotel Continental Lobby - transportation to Swedish Fire Research Board (SFRB)

Frederick K. Mulhaupt, Chair

0900 Carolyn **S.** Cousin, Fire Research Station, *Recent Work on Fire Control Using Fine Water Sprays at the Fire Research Station*

0930 Dr. Ronald L. Alpert, Factory Mutual Research Corporation, *Sprinkler Spray Suppression of Fires*

1000 Larry M. Pietrzak, Mission Research Corporation, *Recent Research and Future Requirements **for** Modeling Fire Suppression Effectiveness*

1030 Break

1100 Dr. Martin Thomas, **UK** Home Office, ***UK** Home Office Research into Domestic Fire Fighting*

1130 John A. Foster and Bryan P. Johnson, UK Home Office, *The Use of Fire Fighting Foams in the UK Fire Service*

1200 Edward K. Budnick, Hughes Associates, Inc. and Dr. Joseph T. Leonard, Naval Research Laboratory, *Feasibility of Fuel Spray Fire Extinguishment with Existing Shipboard Manual Firefighting Capabilities*

1230 Lunch at SFRB

J. M. Craig, Chair

1330 Captain John Floden, Air Force Civil Engineering Support Agency/RACF, *Halon Replacement Program in the US Air Force*

1400 Dr. Robert E. Tapscott, New Mexico Engineering Research Institute, *Second-Generation Replacements **for** Halon*

1430 Dr. Homer *W*. Carhart, Dr. Ronald **S.** Sheinson, Dr. Patricia A. Tatem, and James R. Lugar, Naval Research Laboratory, *Fire Suppression Research in the US Navy*

1500 Break

1530 Henry Persson, Swedish National Testing and Research Institute, *Fire Extinguishing Foams Resistance Against Heat Radiation*

1600 Henry Persson, Swedish National Testing and Research Institute, *A Method **for** Quantitative Measurements of the Extinguishing Capability **of** Powders*

1630 End *of* Formal Presentations

1700 Light Meal at SFRB

1800 Panel Session Begin:
Manual Fire Fighting
Fixed Systems
Next Generation Agents

2000 End of Panel Sessions
Transportation to Hotel Continental

May 7 Thursday

0830 Hotel Continental Lobby - transportation to Swedish Fire Research Board (SFRB)

Cheng Yao, Chair

0900 Panel Sessions Resume
0945 Panel Summary Presentations

1030 Break

1115 Frederick K. Mulhaupt, National Fire Protection Research Foundation, ***Fire Protection for Flammable and Combustible Liquids in Warehouses***

1145 J. M. Craig, Wiltshire County Council Fire Brigade Headquarters, ***Speed of Attack - The Key to Rapid Fire Suppression***

1215 Lunch at SFRB

1330 Conference Summation

1405 Transportation to Hotel Continental or to Stockholm International Airport

May **8** Friday

0830 Hotel Vavaren Lobby - transportation to Swedish National Testing and Research Institute

0900 Welcome to Boras
Prof. **U.** Wickstrom, Swedish National Testing and Research Institute, ***Fire Research at Boras***

0930 Anders Ryderman, Swedish National Testing and Research Institute, ***A State of-the-Art Report on the Sprinkler Research in Sweden***

1000 Laboratory Visits/Fire Tests

1230 End of Tour

1245 Lunch at **Boras**

1400 Conference closes. Transportation provided to Gothenburg/Boras Airport

2.0 RESEARCH PRIORITIES

2.1 Methodology

Prior to the Conference, all participants were asked to identify research priorities for the following Panels:

- **A.** Manual Fire Fighting
- B. Fixed Systems
- C. Next Generation Agents
- D. Other

Responses were received from approximately one-third of the participants. The responses submitted under "Other" did not indicate that any focus for the conference except those identified in the first three panels were necessary. Thus three panel chairs were identified. All of the responses were forwarded to the panel chairs as a starting point for their panel discussions at the conference.

On the second and third days of the conference, the panels met for a total of three hours during the conference to make an assessment of research needs in the area covered by the respective panel. As a result of the discussions during simultaneous panel sessions, three sets of research ideas were prepared and presented to all of the conference participants. The written summary of the findings of each panel are recorded below. Separate short statements identifying the ideas proposed by each panel were written also for the presentation to the conference participants as **a** whole. Using the listing of short statements from each panel, all participants were given the opportunity to vote as a means of establishing a ranking for the ideas. The voting was conducted as part of a break period. All participants were given five votes to assign to research ideas of their choice from each of the three lists prepared by the panels. Each participant was allowed to cast multiple votes for the same research idea within a panel listing.

It was hoped that this would result in grouping that were obviously more significant than others having received greatly different amounts of support in the way of votes from the participants. As the voting time was limited to about 20 minutes, the results only should be viewed as a quick assessment of the position of the group and may not reflect the views of the group if more time was allowed for discussion by the group as a whole. Of course, the relative weightings depend in part on the background, expertise, and current interest areas of the participants. The final rankings of ideas proposed by each panel are listed below according to the number of votes received.

2.2 Panel Summaries

A. Manual Fire Fighting chaired by David M. **S.** Peace

A 1. Media (Agents).

It was thought that research priority should be given to fire suppression media. (The term "media" was preferred to "agents", since the most common firefighting medium, water would not normally be regarded as an "agent", a term usually reserved this context for compounds having significant chemical activity.)

The importance of establishing unambiguously the effect of droplet size and its significance in different types of fire/environment was recognized.

Performance measures/standards relating to fire suppression media also were seen as being important, since they would allow easier comparison of research results, amongst other things. It was suggested that performance might be standardized against a common medium, ideally water, and that the development of a "suppression index" would be helpful.

A 1.1 New Technology.

Multi-phase Suppression: The development of multi-phase media was seen as having potential to improve media performance and to diminish the problems that oxygen entrainment within the extinguishing medium could potentially cause by assisting combustion. Particularly in the case of water as the extinguishing medium, one means of reducing this effect which should be explored would be to inject an inert gas such as nitrogen into the water stream. (Alternatively powders, which when subject to heat within the target area would similarly release either an inert gas or an active fire suppressant, might be introduced into the stream.)

Remote Fog: The effectiveness of finely divided water sprays/fog in suppressing fire is well established. However, the small mass of individual droplets makes it difficult to give them sufficient momentum to travel with any great linear velocity, ***so*** they cannot readily be projected to a remote fire. The concept of remote fog envisages that a solid water stream would be directed at the distant fire, but under the influence of heat and/or impact would disintegrate into a spray of appropriate droplet size. Techniques for coupling energy into, and conveying it along, a coherent water stream which would break into a suitable spray pattern on arrival at the fire location should be explored. Such methods might include the use of acoustic waves and multi-phase agents as above, also dissolved solids and gases.

Bulk Nitrogen: The availability of relatively cheap bulk nitrogen makes it a potential alternative to the use of carbon dioxide as an extinguishant under certain circumstances. If used in its liquid form it would add cooling to its smothering effect, whilst unlike carbon dioxide it **has** no physiological effect at atmospheric pressure.

A2. Tactics.

This area covers a range of potential research areas from operational research of the logistics of firefighting, especially of large fires, to studies of methods of firefighting attack such as the use of venting.

A2.1 New Technology

A2.1.1 AI (Artificial Intelligence) Techniques. Recent developments in artificial intelligence technology now make it possible to model "smart" fire scenarios for training purposes. By the use of production rules and other techniques, firefighting scenarios can be generated which can respond realistically to actions taken by those fighting the fire through the medium of computer simulation. Unlike conventional models, AI based models can generate considerable variety, which makes them more re-usable in repetitive training, since it is more difficult to anticipate how the scenario will develop in any particular play of an exercise.

A2.1.2 Shaped Charges. Shaped explosive charges are now available which can be used rapidly to make apertures in walls and doorways for access and for venting. The viability of this technology in a firefighting environment should be explored to see if the benefits are likely to exceed the obvious hazards.

A3. Equipment.

Although a number of research suggestions had been made about protective clothing by participants prior to the Panel discussions, the Panel elected to set aside discussion of this subject. Research was recommended to develop systems able to give the ideas discussed above (multi-phase media, remote fog, etc.) practical effect.

A3.1 New Technology

A3.1.1 Communications: Recent developments in communications technology offer the prospect of much better quality communications between fireground controls and firefighters; also the provision of real-time data displays to the latter. The potential benefits (and dangers, for example, operator overload and system dependency) should be explored.

A3.1.2 Sensors: Sensor and display technology now has developed to the stage where continuous monitoring of the firefighter's environment is possible for the benefit of both individual firefighters and, in combination with better communication capabilities, for control centers on the fireground. These too should be explored.

A4. Technology Transfer.

It was felt that developments in technology intended for applications unrelated to firefighting were likely to have potential for firefighting and that somehow these should be kept under active review. However, how this might be done in practice was not clear.

A5. Research Procedures and Support.

The conference had demonstrated how fragmented fire suppression research was. Whilst further conferences might be held in due course (and were thought to be highly desirable), in the interim a "common forum" was required through which information could be shared and debated. This might take the form of a newsletter, or perhaps a bulletin board, but before new initiatives were taken in this respect care would have to be exercised that existing facilities were not merely duplicated.

There also was scope for the development of common research techniques to allow direct comparison of research findings.

From the practical firefighter's viewpoint, it was noted that large or otherwise difficult fires occurred only infrequently in any individual's personal experience. This meant there was relatively little opportunity for direct learning about such events, ***so*** far as individuals were concerned. There would be benefit, therefore, in drawing together such experience (by interview and/or questionnaire) and making it more widely available as a (growing) source of categorized practical observations and, where appropriate, of advice on best practice in given circumstances. It was thought that the scientific contribution to the exercise would be in establishing the procedures and categorizations; the actual elicitation of information from firefighters would probably be best carried out by individuals having a background of firefighting themselves.

B. Fixed Systems chaired by Matti Kokkala

The panel identified fifteen areas of research priorities for consideration by their colleagues. They dealt with three broad areas: understanding the agent, understanding the sprinkler performance, and interaction between sprinklers and smoke vents. The text was prepared by the panel chair and some non-substantive editing has been done by the editors.

B1. Predict interaction of suppression agent and fire plume.

Predictive models for the dynamic interaction of agent discharge with a fire plume (for example, **ADD** or penetration efficiency), preferably with correlation formulas, or algebraic submodels, that depend on the measurable characteristics of the agent applicator (for example, sprinkler) are needed to meet the fire challenge. The models also include the capability for simulating a spray device with a theoretical model.

B2. Predict minimum agent application rate for control/suppression of fuel array fires (including storage situations).

Predictive models for the minimum required agent application rate to control/suppress fires involving different types of fuel arrays (for example, RDD, commodity classification tests), preferably using correlation formulas or algebraic submodels, that depend on (a) measurable characteristics of the agent, (b) laboratory scale characterization of the fuel or stored commodity, and (c) geometrical arrangement of the fuel array or storage commodity are needed. The models should include the prediction of agent flows within the fuel array, direct extinguishment by these agent flows and the effect of agent vapors both on the combustion process and on flame heat transfer (for example, flame thermal radiation) process.

B3. Development of smart systems.

According to 1982 NFIRS data, approximately 600 USA deaths and 10,000 injuries in the USA were due to kitchen fires. Research is advocated into multiple suppression sites, activated by a "smart" detector and using water and clean foam. It is suggested that these would be particularly suited to kitchen fires. Alternatively, a flexible tubing system, allowing multiple detection and suppression sites (low flow) in a room could be explored.

B4. Droplet interaction in fire products.

To complete our understanding of the effect of a whole sprinkler spray envelope, we need to study its constituent droplets. We need: (a) to find the effect sprinklers have on conditions in the fire product flow field, including: temperature; average gas density; CO concentration; CO, concentration; evaporation; radiation attenuation; (b) to predict the overall flow fields generated by the spray, which may subsequently influence fire development.

B5. Understanding two-phase flow in spray discharge in fire environment.

No information was provided for this item.

B6. The role of sprinklers in the total fire safety system in buildings.

The relationship between the effectiveness and reliability of sprinkler systems and "tradeoff" benefits affecting building construction needs to be understood.

B7. Study the fire suppression effectiveness of water mist for various fuels and conditions.

The following concepts are suggested: (a) determine optimum spray characteristics; (b) determine extinguishing mechanism(s); (c) determine limits **of** applicability; (d) develop a mathematical model for spray transport and extinction.

B8. The agreement of techniques for characterizing sprays with respect to droplet size and velocity.

It is accepted that the characteristics of sprays with respect to both droplet size and velocity are very important considerations in the performance of fire water sprays in controlling and extinguishing fires.

At present there are a wide variety of techniques for measuring these parameters. However, there is little understanding of the correlation (if any) between the results from different techniques, or indeed data on the repeatability and reproducibility of individual techniques. To further cloud the issue, there are a number of different ways of expression results (for example, VMD, NMD, SMD). If pooling of information is to be possible, there is an urgent need to standardize the techniques and interpretation of data.

B9. Prediction of sprinkler response to a prescribed fire, with or without other activated sprinkler sprays.

Predictive models for the activation of automatic sprinklers due to a prescribed fire source, preferably using correlation formulas, or algebraic submodels, that require measurable sprinkler characteristics as an input are needed. They should include the prediction of recessed sprinkler actuation and actuation in the presence of spray cooling and other effects of previously actuated sprays.

B10. Fixed systems for burning liquids.

There is a lack **of** understanding **of** processes involved in extinguishing liquid fires with fixed water sprays, and consequently, very little modeling work has been carried out. **A** key problem is the heat transfer between the droplets and the hot liquid. In case of liquid jets, one of the problems identified **is** the ability to entrain water into the fuel jet or flame. Another problem is the dispersion of the heavy flammable vapors evaporating from the liquids.

B11. Validating predictive models.

Predictive models are being used with increasing frequency. There is a need to develop experiments with the specific intention of validating existing models.

B12. Study the interaction between sprinklers and smoke vents.

The following items need to be considered: (a) smoke logging (for example, atria, cold smoke); (b) smoke venting (for example, industrial and commercial buildings); (c) smoke control systems. Note: This includes the question of interaction of roof vents and sprinklers. The scrubbing potential of water sprays .... soot, CO_2, HCN, etc. also should be included.

B14. Effectiveness of foam-water sprinkler systems for protection of flammable liquids stored in metal and plastic containers.

No information was provided for this item.

B15. Heat release calorimetry in the presence of water vapor/mist/drops or CO_2 from the agents.

Possible problems include: (a) correction of physical gas properties in the case of water droplets; (b) temperature measurement where water droplets may hit the thermocouple; (c) calculation of oxygen consumption in the case of different instrument combinations. In many cases, problems have already have been solved, but the information cannot be found in the literature.

C. Next Generation Agents chaired by David D. Evans

The panel arrived at sixteen research ideas to present to the conference. These ideas could be organized into four groupings; mechanisms, measurement and testing, new technology systems, and safety. Mechanisms includes the greater understanding of the physical and chemical action of suppression agents. Ideas grouped under measurement and testing call for fire suppression system test data and standardized methods to evaluate fire suppression agents. The new technology systems grouping includes various ideas for new systems or agents. The ideas dealing with environmental and exposure considerations are grouped under safety. The following written statements summarize the panels views on sixteen ideas that were discussed. The text of each statement was written by a member of the panel initially proposing the idea or demonstrating the strongest positive support in the discussion. Some non-substantive editing of the statements has been done by the panel chair for clarity and organization.

MECHANISMS

C1. Modeling suppressant requirements.

Extinguishment agent mechanisms need to be sufficiently understood to allow predictive modeling of agent behavior and requirements. Such a treatment shall strive to relate agent suppression activity in terms of physical-spacial, physical-energy, chemical scavenging, and chemical-catalytic as may be appropriate, as well as incorporating the dynamics of agent application, transport, and dispersion **as** these factors interact with the applicable fire threat dynamics, be it for achieving flame suppression, inerting, explosion protection or explosion suppression.

C2. Spray and jet properties and the interaction of sprays and jets with the fire and plume flow.

This research area deals with the mechanism of dispersion and penetration of the suppressant to the fire. For example, the effectiveness of alternates to Halon 1211 and water mist depend to a large extent on the dispersion and transport of the suppressant agent.

MEASUREMENT AND TESTING

C3. Rapid and accurate droplet (particle) size and velocity distribution measurement.

Droplet (particle) size and velocity measurements are needed to characterize the discharge of most fire suppression and fire fighting equipment, especially for input data to predictive models. Although accurate methods are available today, they involve point wise measurements using photographic methods that are labor intensive to reduce and display. Research is needed to develop a rapid and accurate method of measuring the droplet (particle) size and velocity distribution over a large area and displaying the results for analysis.

C4. Full-scale testing -- choice of scenarios and performance criteria.

The search for alternates to halon fire suppressants have indicated a wide range of fire scenarios which may have a need for different fire suppression systems. These scenarios have to be identified, and expected performance criteria for the suppression system stated in order to give guidance for future experiments.

C5. Development of "bench scale" methods relevant for existing (and possibly new) agents (water, foam, powder, CO_2, halon replacements, etc.).

The methods should be capable of quantifying the effectiveness of the agent, be relevant to the use of the agents in full scale and have a good repeatability and reproducibility. The benefit of such methods would be: (a) results which could be used for comparison between agents, input in computer models, and a basis for cost/benefit analysis; (b) incorporate/evaluate more parameters influencing the extinguishing capability than in present "go/no go tests"; (c) reduce environmental impact from tests; (d) reduce the costs for the tests.

C6. Laboratory-scale procedures for evaluation of halon replacements.

There is a need to ensure that existing procedures (cup burner, explosion sphere) provide useful information on agent "effectiveness" and need additional methods (for example, evaluation of streaming agents). Apparatus and procedure need standardization to allow comparison of data.

NEW TECHNOLOGY SYSTEMS

C7. Investigate the capabilities of water mist for total flooding fire suppression systems including the effects of water additives to enhance performance.

Very small droplet, water mist, fire suppression systems have been tested as a means of providing fire protection in commercial aircraft passenger cabins. The capabilities of water mist as a total flooding fire suppression system should be investigated. This should include the use of water additives such as surfactant to enhance performance. Greater understanding of fire suppression with water mist may enable the installation of systems in areas that have historically been without installed suppression systems, for example, commercial aircraft cabins, or provide an alternative for existing systems.

C8. Advanced agents alternatives to sprinklers.

Specially designed sprinkler systems are being installed in residences to provide fire protection and to reduce the risk of life loss in the event of fire. To increase the number of residences that can be protected, research is needed to develop new fire suppression agents and advanced technology systems as alternatives to sprinklers.

C9. Non-agent techniques.

Study alternatives to the present suppression systems which use agents such as halons, water, dry powder, etc. Alternatives in this case would be things such as energy fields, acoustics, lasers, etc. The concerns of toxicology, combustion byproducts, distribution systems, storage, leakage, environmentally harmful chemicals, etc., all would be eliminated as major concerns.

C10. Incorporated agents.

Study incorporation of fire agents chemically or physically into structural materials ***so*** that the agent would be released during a fire episode. Agents would be at the point of the fire immediately, hopefully controlling a fire situation in initial stages. Agents would be tied into structure, thus would have no environmental or occupational consequences until actual release which would only occur during a fire, therefore, mitigating the impact due to the societal good.

C11. Intelligent sensing combined with an extinguishing system.

New concepts including sensing of the fire position, self adjusting sprinklers orientated against the fire, robots, etc.

C12. Special requirement fires.

There is a lot **of** uncertainties in fire situations, for example, the presence **of** dangerous chemical storage. These situations require optimum choice of agent to avoid creating addition problems during fire suppression. What also must be considered is the logistics of the fire suppression effort. **Is** there a good agent available? What are the delivery demand and tactics required?

SAFETY

C13. Global warming as a screen.

Means are needed to assess the impact/benefit of agents in terms of the environment when used to stop fires quickly versus allowing fires to continue to burn, that is, is more environmental impact found by using the agent or by not using the agent. **A** true understanding of the global warming impact of an agent would allow better decision making in agent selection.

C14. Study terrestrial environmental impact from agents.

The work should include a survey of possible impacts on soil, vegetation, water, fishes, "microlife", etc. which could be expected from use of various fire suppression agents. Test method for the evaluation should be developed and requirements stated. Both the short-term and long-term impact should be considered. The impact versus benefit from various agents (components in the agent) should be evaluated and the need for special agents used exclusively in training should be considered.

C15. Exposure limits for replacement agents.

There is a need for procedures and methodology to set allowable exposure limits for halon replacement agents.

C16. Combustion product evaluation method(s) for halon replacement agents.

There is a need for standard method(s) for determining and quantifying decomposition products from halon replacement agent candidates.

2.3 Ranking of Research Needs

A. Manual Fire Fighting Panel

Number of Votes		Research Needs
21	A1.	Research to produce a better understanding of extinguishing mechanisms of agents. Development of performance measures (international common basis) and standards (relative suppressibility index).
15	A10.	International forum supporting regular meetings, news bulletins, computer links.
13	A4.	Interaction of ventilation with other fire suppression methods.
12	A7.	Remote delivery spray fog.
8	A6.	Research improved communications and computer systems for information exchange and processing between firefighters under operational circumstances (for example, telemetry systems for use with breathing apparatus, use of video and television).
8	A2.	Optimum suppressant characteristics (for example, droplet size).
7	A9.	Technology transfer (for example, expert systems for tactical decision making simulation).
7	A11.	Firefighter protection.
6	A3.	Multi-phase agents (for example, enhancing the effectiveness of a primary agent by delivering it onto a fire with a secondary agent added).
3	A12.	Common research techniques.
3	A5.	Optimizing effectiveness of fire suppression resources (manpower, media, etc.).
0	A8.	Controlled explosives for venting (shaped charges).

B. Fixed Systems Panel

Number of Votes		Research Needs
15	B1.	Predict interaction of suppression agent and fire plume.
13	B13.	Study opportunities and limitations of additives in water to minimize the amount needed for suppression.
12	B8.	Study the agreement of techniques for characterizing sprays with respect to droplet size and velocity (and thrust force).
11	B15.	Study heat release calorimetry in presence of water or carbon dioxide.
10	B7.	Study the effectiveness of water mist to control or to suppress fires in various fuels and under various conditions.
9	B2.	Predict minimum agent application rate for control/suppression of fuel array fires, including storage.
9	B6.	Understanding the relationship between the effectiveness and reliability of sprinkler systems, and trade-off benefits affecting building construction.
9	B11.	Validating predictive models.
6	B4.	Droplet interaction in fire products (including effects on flow field).
5	B3.	Development of "smart systems".
5	B9.	Prediction of sprinkler response to a prescribed fire, with or without over activated sprinklers.
1	B10.	Fixed systems for suppressing fires in combustible/flammable liquids.
0	B5.	Understanding two-phase flow in spray discharge in fire environment.
0	B12.	Study the interaction of sprinklers and fire vents.
0	B14.	Effectiveness of foam-water sprinkler systems for protection of flammable liquids stores in metal and plastic containers.

C. Next Generation Agents Panel

Number of Votes		Research Needs
16	C2.	Dispersion and transport of agents. Investigate interaction of agent sprays and streams with fire jets and plumes.
13	C1.	Modeling suppression. Study extinguishment agent mechanisms to develop predictive models for agent behavior and requirements.
13	C7.	Water mist. Investigate the capabilities of water mist for total flooding fire suppression systems including the effect of water additives to enhance performance.
11	C5.	"Bench-scale" test methods. Development of measurement methods capable of quantifying the effectiveness of agents with good repeatability and reproducibility.
10	C3.	Drop size measurement. Large space, rapid, and accurate drop (particle) size and velocity distribution measurement.
7	C9.	Non-agent techniques. Study alternatives to the presently-used methods which employ an agent such as halons, water, dry powder, etc. Alternatives in this case would be things such as energy fields, microwave, laser, acoustics.
7	C13.	Global warming as a screen. Study impact/benefit of agents in terms of impact when used to stop fires versus allowing fires to burn. **Is** there more impact from use of agents or from non-use of the agent?
7	C4.	Full scale testing. Study choices of scenarios and performance criteria for development of new agents and systems.
5	C14.	Terrestrial environmental impact of agents. Survey of possible impacts from agents on soil, water, vegetation, fish, etc. Develop test methods to evaluate impact.
5	C6.	Laboratory-scale techniques for evaluation of halon replacements. Standardization and assessment of existing (cup burner, explosion sphere) methods and development of new methods (for example, streaming agent evaluation).

Number of Votes		Research Needs
4	C10.	Incorporating agents. Study incorporation of fire agents, by either chemical or physical means, into structural materials ***so*** that the locking mechanism would release the agent during a fire episode.
4	c12.	Special requirement fires. Investigate optimum choices of agents for dangerous chemicals and hazardous material fires.
3	C16.	Combustion product evaluation method(s) for halon replacements. Need standard method(s) for determining and quantifying decomposition products from halon replacement candidates.
0	C11.	Intelligent sensing and suppression. New concepts for sensing fire and automatic adjustments of suppression.
0	C15.	Exposure limits for replacement agents. Need procedures/methodologies to establish allowable exposure limits for halon replacement agents.
0	C8.	Advanced agents. To enhance the number of residences that can be protected, research is needed to develop new fire suppression agents and advanced technology systems as alternative to sprinklers.

3.0 RECOMMENDATIONS

The purpose of the ranking was to obtain a quick assessment of the priorities of the participants without the need to reach a consensus through discussion. The rankings should be considered with that thought in mind. The rankings do indicate some clear priorities. The recommendations from this conference are the research needs identified by the panels that received 10 or more votes from the group. Among these recommendations four were found in more than one panel listing. They are:

- Research related to the use of water mist or fog in fire suppression **(A7,** B7, **C7),**
- Research related to understanding and modeling suppression mechanisms (A1, C1),
- Research related to better understanding of the physical interaction of suppression agents in the form **of** sprays and stream (B1, **C2),**

- and possible as an extension of that research, the development of practical means to determine droplet size and velocity (**B8,** C3).

In addition to those research needs, there were five others. They are:

- The need to continue the international forum for discussion of fire suppression in some manner (A10).
- The need to understand the interaction of vents with suppression systems (A4).
- The need to know more about the capabilities of additives to water to enhance its fire suppression effectiveness (B13).
- The need to be able to measure the heat release rate of burning materials in the presence of water and carbon dioxide (B15).
- The need for "Bench-scale" test methods capable of quantifying the effectiveness **of** fire suppression agents (C5, C6).

The above statements reflect research needs that the group feels will provide a benefit to fire suppression. There also may be a feeling that some areas, although important, are being addressed sufficiently. For example, the panel on Next Generation Agents identified several research needs dealing with the environmental effects of halons and candidate replacements (C6, **C13, C14,** C15, C16). Possibly, because of the large amount of current halon related research activity worldwide, these needs received only modest support.

It is easy to see how the results of the ranking and the research needs that were assembled by the panels depends substantially on the background, expertise, and current interest areas of the participants. Never-the-less, these needs and their rankings can serve as a starting point for discussions about future research to be performed in fire research organizations worldwide.

4.0 SUMMARIES OF CONFERENCE PAPERS[1]

SUPPRESSION RESEARCH: USER NEEDS

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Even though almost every fire is fought, we do not already posses enough knowledge to agree upon the quantity of water needed to fight a fire of a given size in area. Recommendations vary by a factor of ten. From the user point of view, a sequence of events in a typical response to a fire can be used as the basis for structuring fire suppression research. This includes: demands on fire fighting resources created by the fire, delivery systems, suppression agents, procedures. Other aspects are independent of the sequence including modelling, storing agent, and toxic hazards. Needs as expressed by users, such as the fire service, to needs as seen by fire suppression researchers.

SUPPRESSION RESEARCH: STRATEGIES

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Millions of unwanted fires occur each year. More effective fire suppression is a means to minimizing property damage and life loss due to fire. The Damkoler number, which is the ratio of the characteristic time for flow or diffusion of reactants to the time required for reaction, is the basis for a fire extinction criterion that may provide insight for many fire suppression situations. A correlation of wood crib fire extinction data is used to show the predictive capabilities that can be developed from experimental results alone, even without complete and general understanding of the fire suppression phenomena. The use of computer field modeling techniques is discussed as a means to generate insight into the complex physical interactions that occur during fire suppression in an enclosure.

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[1]Complete papers appear in the First International Conference on Fire Suppression Research Proceedings.

COMPUTER MODELLING OF EXTINCTION OF METHANE-AIR PREMIXED FLAMES BY THERMALLY STABLE GASES

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A computer model, which combines an energy-based approach with chemical-kinetic considerations, has been developed to examine the extinction of premixed methane-air flames by four thermally stable gases; carbon dioxide, gaseous water, nitrogen and helium. The model contains **23** chemical species and 73 elementary reaction steps. The chemical reactions were simulated with the Sandia CHEMKIN code using a well-stirred reactor concept. The simulation showed that, when the temperature of the mixture was reduced to a critical level the production of **O,** H and OH radicals was reduced and the mixture was extinguished. Thus, an effective fire suppressant must have the ability to reduce the concentration of these radicals in flames, either by chainbreaking reactions (chemical inhibition) or by reducing the flame temperature (thermal effects). The calculated species concentrations and temperature were found to agree, with reasonable accuracy, with the results obtained from the laboratory measurements. The model can be extended to deal with even non-gaseous suppressants, such as dry chemicals and water droplets, and other fuels provided that reasonably accurate reaction kinetic data are available.

OVERVIEW OF FMRC'S SPRINKLER TECHNOLOGY RESEARCH

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An overview of the sprinkler technology research which has been carried out at FMRC over the last two decades is presented. The Large-Drop sprinkler (1971-1980) for the control of high-challenge storage fires, the Residential sprinkler (1976-1979) for maintaining a survivable environment in residential areas, and the Early Suppression Fast Response (ESFR) sprinkler system (1984-1986) for the suppression rather than the control of high challenge fires were developed. **A** deterministic computer model for predicting sprinkler fire suppression capability is being developed. This model will be used as a guide to develop the computer simulation-based early suppression sprinkler system design.

RACK STORAGE FIRE SUPPRESSION BY SPRINKLERS. WORK AT THE RESEARCH STATION FOR FIRE PROTECTION TECHNOLOGY

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It will be reported on experiments of fire and fire suppression by sprinklers on various materials which are arranged as rack storage respectively as block storage. The water distribution of as many as five sprinklers could be determined as a function of the sprinkler type, their height and the volume flow of the sprinkler type, their height and the volume flow of the emerging quantity of water. A method of calculation for the superposing water distribution up to five sprinklers was developed by the water distributions measured with one sprinkler. The tests in the block storage revealed that the sprinkler released much earlier than in the rack storage, but that the fire could not be extinguished completely as a result of fire clusters in spite of the higher quantity of extinguishing water.

FIRE SUPPRESSION RESEARCH IN NORWAY

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The fire suppression research in Norway is closely connected to the offshore industry, and the test facilities which were established in the last six years have given an opportunity to test realistic fires and suppression systems. The explosion suppression activity performed by CMI in Bergen also is **of** great importance, and the results may give guidance to optimum choice of water droplet size and the application rates to prevent high over-pressures in an explosion, simultaneously with high fire control and extinguishing effect. The results of the research also will be implemented in onshore buildings and industry. The Norwegian authorities are currently financing a study of minimum water application rates in sprinkler-protected buildings, especially with respect to the effect **of** fine water sprays.

FINE WATER SPRAY FIRE SUPPRESSION PROJECT

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This paper describes the experimental portion of a research program involving fine water spray fire suppression systems presently underway at the National Fire Laboratory, Institute for Research in Construction, National Research Council Canada. The project is funded jointly by National Defence Canada and National Research Council Canada. The research will identify the key engineering parameters needed to design very fine water spray systems to suppress flammable liquid pool fires in the Forward Auxiliary Machinery Room (FAMR) of a Halifax Class frigate of the Canadian Navy, and will result in a design guide for Navy use.

FIXED WATER SPRAYS AGAINST OPEN LIQUID POOL FIRES

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A series of extinguishing tests was carried out on ten liquids with flash points in the range of -6°C to +234°C applying seven different sprinklers or nozzles. Pool size was varied within the range 0.4 m^2 -12 m^2, and the nozzle height within the range 3 m **-** **8** m. In this paper the results of the tests are summarized. Observations and effects **of** pool size, nozzle type, flash point, application rate, preburn time and nozzle height are discussed. Recommendations are made on the required application rates for extinguishment.

CHARACTERIZATION OF WATER DROPS FROM SPRINKLER SPRAYS

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In order to predict the performance of a sprinkler or a spray head in a fire scenario it is necessary to model the interaction of water drops with the thermally buoyant fire gases. Such modelling requires a detailed knowledge of the mean drop size, the drop size distribution, drop velocity and trajectory. Many existing systems for the characterisation of drops are indirect in that an optical property is measured and the results are subject to "black box" data processing. A direct method has been developed using a synchronised metal vapour laser and high speed cine camera with appropriate optics. Results of spray drop characteristics from several sprinklers are presented.

IMPACT OF FIRE RESEARCH ON AUTOMATIC SPRINKLER SYSTEM DESIGN

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The extent to which fire research has affected installation of automatic sprinkler systems is discussed, along with background information relative to the control of system design practices by recognized installation standards. Differences are noted in the levels of acceptance of product-specific research and generalized research results. Specific examples by which installation standards have encouraged the use of new research results are provided, along with an example of an area in which current research knowledge provides the ability to modify the minimum requirements of the standards. The role of the fire protection engineer in the system design process is discussed as the key to timely and appropriate use of research results.

A STUDY OF PARAMETERS INFLUENCING THE RTI VALUE

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Thermal response models for glass bulb sprinklers have been studied considering the following thermal response parameters; the Rate of Time Index (RTI), the conduction parameter (C) and the Change of Phase Parameter (CHP). The RTI parameter reflects the thermal time constant of the glass bulb and the C parameter the heat conduction loss to the sprinkler fitting. The CHP parameter is thought to be a factor accounting for a time delay shortly before activation caused by heat absorption of the operating medium or work needed to shatter the glass bulb. Combinations of one, two and three parameters have been used to predict response times for various plunge and ramp test conditions, as well as for a wide range of growing fires. Field model calculations of convective heat transfer to a bulb-type sprinkler with the frame arms orientated parallel with the air flow indicate that the heat transfer varies with the square root of the velocity as assumed in the original RTI theory. The RTI theory is therefore deemed to be valid for the simulated sprinkler irrespective of the orientation.

MATHEMATICAL MODEL OF THE INTERACTION OF SPRINKLER SPRAY DROPS WITH FIRE GASES

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A computer code, SPLASH, has been devised to examine the interaction of water drops with fire gases and so permit the analysis of active fire protection system design and operation in the event of a fire in a building. The code is based on a comprehensive mathematical model detailing the physical phenomena involved and a library of drop characteristics, including diameter, speed and trajectory, obtained from a number of commercial sprinklers using a high speed microcinematography technique.

RECENT WORK ON FIRE CONTROL USING FINE WATER SPRAYS AT THE FIRE RESEARCH STATION

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This paper describes two areas of study at the Fire Research Station involving the use of fine water sprays for fire control. The first area of study described covers an investigation conducted for the Civil Aviation Authority on the effectiveness of on-board water spray systems to limit fire growth and spread within the passenger cabin should an aircraft be involved in a fire following a survivable crash. The second study investigated the potential of fine water sprays to extinguish fires in enclosed spaces using a test rig designed to simulate a computer cabinet. Six nozzles, capable of supplying sprays with mean droplet sized in the range $200\mu m$ - $300\mu m$, were installed in the walls of the cabinet, and spray supplied from different combinations of these nozzles. It was found that, in the range of experiments conducted to date, when the crib was located below the nozzle rapid extinction could be achieved. The introduction of obstructions always reduced this performance, even at maximum spray throughput. This programme is ongoing.

MODELING OF SPRINKLER SPRAY SUPPRESSION OF FIRES

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An overview of fire suppression modeling is provided, along with a more detailed discussion of the process of developing needed correlation formulas to predict sprinkler spray penetration to the base of a fire plume, spray cooling of the fire-induced flow field and sprinkler actuation in the presence of previously actuated droplet sprays. It is concluded that we must not only gain confidence in the ability of various modeling techniques to predict important aspects of fire suppression through extensive comparisons with validation experiments, but we must also exercise existing modeling techniques world-wide to the greatest extent possible, for a wide range of fire and sprinkler scenarios, ***so*** that submodel formulas will be available for predicting the overall fire suppression process.

RECENT RESEARCH AND FUTURE REQUIREMENTS FOR MODELING FIRE SUPPRESSION EFFECTIVENESS

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The paper describes an existing computerized fire suppression model of post-flashover compartment fires using manual water spray including experimental comparisons and significant sensitivities. This is followed by recommended future requirements for modeling both manual and in-place water spray as well as manual application of foam.

UK HOME OFFICE RESEARCH INTO DOMESTIC FIRE FIGHTING

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The United Kingdom Fire Service tackles the majority of domestic dwelling fires with its hose reels. Consequently, effort has been directed towards improving their performance. High pressure supplies offer more tactical options to the firefighter and, whilst some hose reel branches offer finer sprays than others, ***so*** improving the initial cooling of the air in a room fire, and the use of additives can improve the time to control a fire, it is the versatility of the branch which is most important.

THE USE OF FIREFIGHTING FOAM IN THE UK FIRE SERVICE

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The UK Fire Service used the majority of its firefighting foam during training. Nevertheless, for the extinction of most Class B fires, there is no substitute for foam. FEU work has been identified suitable foam concentrates and application methods for use by the UK Fire Service. However, the current high quality of foam concentrates currently available is threatened by a new European Standard which is **soon** to be introduced.

FEASIBILITY OF FUEL SPRAY FIRE EXTINGUISHMENT WITH EXISTING SHIPBOARD MANUAL FIREFIGHTING CAPABILITIES

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Large-scale JP-5 fuel spray fires were conducted in the open to evaluate the effects of existing U.S. Navy shipboard manual firefighting capabilities. Test fire ranged from 6 to 56 MW in intensity with flame heights of 6 to 15 m. While complete extinguishment was typically not achieved, application of AFFF at 3.8 and 6 L/s significantly reduced fire size, lowering the incident radiation by 64 to 93 percent near the fire. The addition of PKP or Halon 1301 in parallel with AFFF fully extinguished the spray jet fires. AFFF/fuel mass flow ratios of 13 to 15 were 3 to 6 times higher than ratios reported for water effects on gas jets at a similar scale. However, the ratios are within the practical limits associated with manual suppression inefficiencies.

HALON REPLACEMENT PROGRAM IN U.S. AIR FORCE

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The United States Air Force has implemented a significant research program to find a Halon 1211 replacement. Numerous compounds were considered to find the best candidates. Laboratory-, small-, medium-, and large-scale fire testing was done to narrow the candidate pool to a few best compounds. Tests to determine occupational and environmental safety were done in addition to tests of fire fighting effectiveness. final selection of a candidate replacement agent will most likely occur in late 1992 upon completion of the validation testing now underway.

SECOND-GENERATION REPLACEMENTS FOR HALONS

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Halocarbon fire suppressants having a fire suppression efficiency in most applications equal to that of the halons now used require the presence of bromine and/or iodine. Such chemical action agents (CAAs) suppress fires primarily by removal of flame free radicals. Since bromine (and, perhaps, iodine) is a potent depleter of stratospheric ozone, CAAs will have low ozone depletion potentials (ODPs) only if the atmospheric lifetime can be made sufficiently short. This paper discusses three mechanisms for removal of CAAs from the atmosphere and presents some example compounds.

FIRE SUPPRESSION RESEARCH IN THE U.S. NAVY

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The use of water mist, finding replacements for halons, and the use of nitrogen pressurization for confined spaces are the three U.S. Navy fire suppression research topics to be presented in this paper. Water, the most commonly used fire suppressant, can be more efficiently used in the form of a mist. Halon usage will be greatly curtailed because of its contribution to depletion of the stratospheric ozone layer. U.S. Navy research in several areas is presently being conducted to determine the best replacements or alternative strategies to the use of halons. In confined pressurizable spaces, as found in submarines, the use of nitrogen pressurization has proven to be an effective fire suppressant while still providing a habitable environment.

FIRE EXTINGUISHING FOAMS RESISTANCE AGAINST HEAT RADIATION

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A test series has been conducted where various types of foams have been subjected to heat radiation. Foam was generated with the small scale "UNI-86" test nozzle and collected in a glass beaker with a diameter of 225 mm and 100 mm height. The foam destruction was recorded visually and the portion evaporated and drained, respectively, was achieved by weight measurements. The heat radiation was generated using a cone radiator, similar to the one used in the ISO "Ignitibility Test". Nominal radiation levels used in the tests were 0, 5, 15, 25 and 35 Kw/m^2. Some tests were also conducted with a layer of fuel in the glass beaker. A small pilot flame was located just above the foam surface and time to ignition was recorded.

A METHOD FOR QUANTITATIVE MEASUREMENTS OF THE EXTINGUISHING CAPABILITY OF POWDERS

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A method is presented for quantitative measurements of the extinguishing capability of powders. A test is proposed which provides quantitative information about the efficiency of the powder on B- and C-fires by using a large gas diffusion flame. The tests are conducted by using a tubular burner, where the propane gas and the powder are mixed before they reach the burner outlet. The quantity of powder supplied is adjusted until the fire is extinguished. The specific extinguishing media requirement (Required Extinguishing Media Portion, REMP), i.e. the ratio between the quantity of powder supplied and the quantity of propane gas supplied, is given as a quantitative measure of the efficiency of the powder. REMP = m_e/m_g. The lower the REMP-value, the more efficient the powder. Methods also are proposed for testing the efficiency against A-fires and the discharge performance. Although the methods soon will be published as a NORDTEST method, NT FIRE **044,** there is need of further research in certain areas which are indicated in the paper.

FIRE PROTECTION FOR FLAMMABLE AND COMBUSTIBLE LIQUIDS IN WAREHOUSES

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The environmental impact of flammable and combustible liquid fires, and measures to suppress them, limits strategic options available to the fire safety community. At the same time, environmental concerns are stimulating fire test programs and yielding improved fire safety. The Research Foundation has conducted the International Foam-Water Sprinkler Research Project, the National Flammable/Combustible Liquid Container Storage Research Project, and the Wholesale/Retail Occupancy Fire Research Project to evaluate fire challenges and measure suppression effectiveness. The report summarizes fire test data. The foam-water sprinkler project evaluated the performance of closed-head AFFF foam-water sprinklers versus liquid spill fires in flammable liquid warehouses. An international literature review and fire test series were conducted. Successful large-scale tests suppressed the fires with four or five sprinkler heads activating. The container storage project assumed conventional warehouse fire sprinkler design parameters, and varied the packaging fire retardant characteristics in small- and large-scale verification fire tests. The project also developed consensus for new fire performance test protocols for 1-gallon and smaller containers of flammable and combustible liquids. The wholesale/retail project is testing the effectiveness of water fire sprinklers versus flammable and combustible liquid fires as might occur in the new warehouse/showroom retail occupancies. Ceiling-only and in-rack sprinkler systems are being evaluated.

SPEED OF ATTACK - THE KEY TO RAPID FIRE SUPPRESSION

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The principle of rapid attack upon fire can be used as a basis for improving worldwide fire protection policies. The following needs are identified: Fire prevention programmes must be continued; manual methods of "first strike" firefighting must be taught efficiently or not attempted at all; advances in information and communications technology are harnessed to speed and to simplify methods of summoning firefighter assistance; constant review of fire brigade resources to ensure that they are adequate and properly deployed; vehicles and equipment improvements developed for smaller, faster and more versatile fire and rescue vehicles. Automatic sprinklers offer the best method of both detecting and attacking the majority of fires in their early stages. Extended use of automatic sprinklers may bring about significant improvements in fire protection.

STATE OF THE ART SPRINKLER RESEARCH IN SWEDEN

Anders Ryderman
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Fire suppression research in Sweden started in the beginning of the eighties by the formation of Brandforsk (The Swedish Fire Research Board), and SP (the Swedish National Research and Testing Institute) was very early involved in fire extinguishing media and extinguishing systems research programs. The first project we performed with the new test equipment had the goal to evaluate the RDD measurement (Required Delivered Density). Thermal response models for glass bulb sprinklers have been studied; the Rate of Time Index (RTI), the Conduction parameter (C) and the Change of Phase Parameter (CHP). Future research work includes: Study of a system based on FPC and RDD measuring technique for classification of goods; modelling of fires in rack storage; experimental and theoretical study of water fog **as a** fire extinguishing media. One of the most important things is to develop a standardised method for classification of commodities and other types of fires, such as fires in engine rooms, power plants, production and storage of chemicals. Our idea is to find a classification system which takes into account the fire property of the material as well as suppressability and environmental influence from smoke and extinguishing media during a fire.

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